(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 396 603 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent: **26.06.1996 Bulletin 1996/26**

(21) Application number: **89901560.6**

(22) Date of filing: **18.01.1989**

(51) Int Cl.[6]: **C23C 14/22**, C23C 14/32, H01J 37/32, H05H 1/50

(86) International application number: **PCT/FI89/00008**

(87) International publication number: **WO 89/06708 (27.07.1989 Gazette 1989/16)**

(54) PROCEDURE AND APPARATUS FOR THE COATING OF MATERIALS BY MEANS OF A PULSATING PLASMA BEAM

VORRICHTUNG UND VERFAHREN ZUR BESCHICHTUNG VON MATERIALIEN DURCH EINEN PULSIERENDEN PLASMASTRAHL

PROCEDE ET APPAREIL DE REVETEMENT DE MATERIAUX AU MOYEN D'UN FAISCEAU DE PLASMA PULSE

(84) Designated Contracting States: **AT BE CH DE FR GB IT LI LU NL SE**

(30) Priority: **18.01.1988 FI 880203**

(43) Date of publication of application: **14.11.1990 Bulletin 1990/46**

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Description

The present invention relates to a procedure and an apparatus for the coating of materials.

Coatings consisting of or resembling a diamond material have properties similar to corresponding traditional diamonds. The first property is hardness. Another significant mechanical property is a low friction coefficient. The resistance to wear is also extraordinary. Furthermore, such a coating remains unchanged in all known kinds of acid and base. Diamond and diamond-like materials are therefore especially suited for the coating of objects subject to wear or corrosion, e.g. bearings without lubrication. A further notable factor is the high refraction index of diamonds.

In microelectronics, the high thermal capacity and thermal conductivity of diamond and diamond-like coatings provide significant advantages. To achieve higher component densities and speeds, it is necessary to reduce the structural size of integrated circuits. This makes it more difficult to remove the heat generated by the electric current, and it also means that good conductivity is more important than before.

In current practice, diamond-like coatings are produced by direct ion beam treatment, which is based on increasing the energy of ions. In direct ion beam coating, the coat is grown on the surface of the object material directly from the ion beam, from which the impurities have been removed by means of a separating magnet. The worst problem with this method is the difficulty of constructing an ion source of sufficient capacity. Another currently used method for growing a diamond coat is based on plasma-assisted vapour phase coat deposition (PAVCD). In this method, a crystalline diamond is grown from a mixture of methane and hydrogen. Unlike the method based on the use of an energetic ion beam for growing a diamond coat, whicn can be implemented in room temperature, the PAVCD method requires a high temperature of the order of 800°C. This is a serious disadvantage in view of the coating of conventional materials used in tools or construction.

A method of and apparatus for coating a substrate is known from the document "Proceedings of the IEEE, Vol. 60, No. 8, August 1972, pp. 977-991, A.S. GILMOUR JR. & D.L. LOCKWOOD: Pulsed Metallic Plasma Generators". This document describes the deflection of a plasma resulting from the use of a magnetic-field coil also in the case of the magnetic field coil being tilted with respect to the axis of the generator.

It is the object of the present invention to provide a method of and apparatus for coating a substrate in which the draw backs referred to above are eliminated.

This object is solved in accordance with the present invention by a method including the features of claim 1 and by an apparatus including the features of claim 5. Advantageous embodiments are described in the dependent claims.

The advantages of the procedure are that it is simple and enables even large surfaces to be coated.

In a preferred embodiment of the method of the invention, the plasma beam consists of particles emitted from at least one electrode.

In another preferred embodiment of the method of the invention, the coating is performed in a vacuum.

In a further preferred embodiment of the method of the invention, the coating process uses a gaseous medium which reacts with charged particles.

In another preferred embodiment of the method of the invention, the plasma beam is deflected by a magnetic field produced by means of a deflected coil.

In a preferred embodiment of the apparatus, to prevent oscillation of the voltage, the apparatus is provided with a diode connected in parallel with the capacitor.

In a further preferred embodiment of the apparatus of the invention, the apparatus is provided with at least one igniter circuit to produce an arc between the electrodes.

Another preferred embodiment of the apparatus of the invention is characterized in that at least one of the electrodes is of a cylindrical form.

Another preferred embodiment of the apparatus of the invention is characterized in that at least one of the electrodes is placed wholly or partially inside the coil.

Another preferred embodiment of the apparatus of the invention is characterized in that at least one of the electrodes is provided with at least one hole through which the plasma beam is directed.

Another preferred embodiment of the apparatus of the invention is characterized in that the igniter circuit comprises a metal rod inside each cylindrical electrode, another capacitor and a voltage source, which are used to produce an igniting arc between said electrode and said rod.

Another preferred embodiment of the apparatus designed for implementing the procedure of the invention is characterized in that the igniter circuit has at least one external spark gap or switch.

In the following, the invention is described by the aid of an example with reference to the attached drawing, which represents a plasma accelerator and an object to be coated. For the coating of a material, the plasma accelerator produces a cloud of plasma from carbon. This cloud is accelerated towards the object to be coated, and deflected by the magnetic field, whereupon the plasma beam strikes the surface of the object. Both the plasma accelerator and the object to be coated are placed in a vacuum. The plasma accelerator has a cylindrical cathode 1 made of solid carbon, which is connected to the negative terminal of the first voltage source 2 and to the first terminal of the first capacitor C1. The disc-shaped anode 3, which has a hole in the middle, is connected to a cylindrical coil 4 formed from a copper conductor. The coil is deflected and connected at one end to the positive terminal of the first voltage source 2 and to the other terminal of the first capacitor C1. Connected to the terminals of the capacitor C1 are also a

diode D and a variable resistor R. The cathode 1 is partially and the anode 3 wholly inside the coil 4.

Inside the cathode 1 is a metal rod 5. The cathode 1 and the rod 5 together form a second voltage source 6 and, together with a second capacitor C2, an igniter circuit. The second voltage source 6 is variable. The cathode 1 is connected to the positive terminal of the second voltage source 6 and to the first terminal of the second capacitor C2. The metal rod 5 is connected to the negative terminal of the second voltage source 6 and to the other terminal of the second capacitor C2.

The plasma accelerator performs the coating of a metal plate 7 as follows. The first voltage source 2 charges the first capacitor C1, connected in parallel with the voltage source. The second voltage source 6 charges the second capacitor C2, likewise connected in parallel with it, until a spark-over occurs across the air gap between the cathode 1 and the metal rod 5, so that an arc is generated in said air gap. This arc discharges the second capacitor C2 and correspondingly produces an arc between the cathode 1 and the anode 3. As a result, the cathode begins to emit a beam of carbon particles consisting of charged ions and uncharged atoms. The arc between the cathode 1 and the anode 3 discharges the first capacitor C1, and the arc is extinguished when the capacitor voltage falls below the level required for maintaining the arc. In this manner, a pulsating plasma beam is produced from carbon ions and carbon atoms. The duration of a pulse is determined by the capacitance of the first capacitor C1.

Connected in parallel with the first capacitor C1 are a diode D, whose function is to remove the reverse voltage produced across the first capacitor C1 by the oscillating circuit consisting of capacitor C1 and coil 4, and a variable resistor R protecting the diode D.

The plasma beam is accelerated through the magnetic field generated by the winding 4. Since the coil 4 has a curved shape, the charged ions passing through the hole 8 in the anode 3 will follow the curvature of the magnetic field, whereas uncharged particles will proceed straight past the plate 7. In this manner, uncharged particles are separated from the charged ions. The plate 7 to be coated is placed close to that end of the coil 4 which is connected to the first voltage source 2 and the first capacitor C1. Since the magnetic field generated by the coil 4 diverts the charged ions but does not affect the passage of uncharged particles, the plate to be coated is only struck by ions accelerated by the magnetic field.

When an ion with sufficient engergy, imparted by the magnetic field, hits the surface of the plate 7, it is able to penetrate into the surface material. In the course of the next 10-11 s., the microscopic area around the penetrating ion undergoes remarkable changes. A significant proportion of the atoms in the plate surface have been displaced from their normal lattice positions, and the proportion of vacancies and intersitial atoms may reach a level of several per cent. The conditions inside a cascade like this correspond to a temperature of several thousand °C, although the ambient temperature remains unchanged. Moreover, the pressure at the edges of the cascade increases. As a result of the process described, a diamond-like coat is produced on the surface of the plate 7.

Instead of a vacuum, it is also possible to use a gaseous medium which reacts with the ions in the surface of the material to be coated, producing e.g. a coat of boron nitride. In the igniter circuit, the arc between the cathode 1 and the metal rod 5 is automatically extinguished when the voltage across the second capacitor C2 falls below the level required for maintaining the arc. The igniter circuit may also employ an external spark gap 9 or switch to extinguish the arc between the cathode 1 and the metal rod 5 at a desired moment.

It is obvious to a person skilled in the art that different embodiments of the invention are not restricted to the examples described above, but that they may instead be varied within the scope of the following claims.

Claims

1. A method for coating a substrate, comprising the steps of:

   - generating a pulsating plasma beam of ions and uncharged particles of a coating material;
   - accelerating and guiding the ions of the plasma beam along a curved magnetic field to the substrate;
   - the curvature of the magnetic field being selected such that the uncharged particles of the plasma do not reach the substrate.

2. A method according to claim 1 wherein the plasma beam is generated by an arc discharge produced between a cathode (1) consisting of the coating material and an anode (3).

3. A method according to claim 2 wherein the arc discharge is pulsating.

4. A method according to any one of claims 1 to 3 wherein the curved magnetic filed is generated by a coil (4) having a curved shape.

5. An apparatus for coating a substrate comprising:

   - a coating material electrode (1) and another electrode (3);
   - at least one voltage source (2) and at least one capacitor (C1) for generating a pulsating plasma beam consisting of the coating material; and
   - at least one deflection coil (4) for generating a curved magnetic field;

- the curved magnetic field accelerating the ions of the plasma beam and guiding the ions to the substrate (7) such that uncharged particles of the plasma beam will proceed straight past the substrate (7).

6. An apparatus according to claim 5 wherein at least one of the electrodes (1,3) is of a cylindrical form.

7. An apparatus according to any one of claims 5 and 6 wherein at least one of the electrodes is placed wholly or partially inside the coil (4).

8. An apparatus according to any one of claims 5 to 7, further comprising an igniter circuit for producing an igniting arc between the coating material electrode (1) and the other electrode (3), the igniter circuit including a conducting rod (5) inside the coating material electrode (1) which is of a cylindrical form, and including another capacitor (C2) and a voltage source (6).

9. An apparatus according to claim 8 wherein the igniter circuit is provided with at least one external spark gap (9) or switch.

Patentansprüche

1. Verfahren zum Beschichten eines Substrats, umfassend die Schritte:

   - Erzeugen eines pulsierenden Plasmastrahls aus Ionen und ungeladenen Partikeln eines Beschichtungsmaterials;
   - Beschleunigen und Lenken der Ionen des Plasmastrahls entlang eines gekrümmten Magnetfeldes zum Substrat; wobei
   - die Krümmung des Magnetfeldes so gewählt wird, daß die ungeladenen Partikel des Plasmas nicht das Substrat erreichen.

2. Verfahren gemäß Anspruch 1, worin der Plasmastrahl durch eine Lichtbogenentladung erzeugt wird, die zwischen einer Kathode (1), die aus dem Beschichtungsmaterial besteht, und einer Anode (3) erzeugt wird.

3. Verfahren gemäß Anspruch 2, worin die Lichtbogenentladung pulsierend ist.

4. Verfahren gemäß einem der Ansprüche 1 bis 3, worin das gekrümmte magnetische Feld durch eine Spule (4) mit einer gekrümmten Form erzeugt wird.

5. Vorrichtung zum Beschichten eines Substrats umfassend:

   - eine Elektrode (1) aus Beschichtungsmaterial und eine andere Elektrode (3);
   - mindestens eine Spannungsquelle (2) und mindestens einen Kondensator (C1) zum Erzeugen eines pulsierenden Plasmastrahles bestehend aus dem Beschichtungsmaterial; und
   - zumindest eine Ablenkspule (4) zum Erzeugen eines gekrümmten Magnetfeldes; wobei
   - das gekrümmte Magnetfeld die Ionen des Plasmastrahles beschleunigen und die Ionen zu dem Substrat (7) so lenken, daß die ungeladenen Partikel des Plasmastrahles geradeaus an dem Substrat (7) vorbei fortschreiten.

6. Vorrichtung gemäß Anspruch 5, worin zumindest eine der Elektroden (1, 3) eine zylinderförmige Form besitzt.

7. Vorrichtung gemäß einem der Ansprüche 5 und 6, worin zumindest eine der Elektroden vollständig oder teilweise im Inneren der Spule (4) angeordnet ist.

8. Vorrichtung gemäß einem der Ansprüche 5 bis 7, weiterhin umfassend einen Zündvorrichtungskreis zum Erzeugen eines Zünd-Lichtbogens zwischen der Elektrode (1) aus Beschichtungsmaterial und der anderen Elektrode (3), wobei der Zündvorrichtungskreis einen leitfähigen Stab (5) im Inneren der Elektrode (1) aus Beschichtungsmaterial umfaßt, der eine zylinderförmige Form besitzt, und einen anderen Kondensator (C2) und eine Spannungsquelle (6) umfaßt.

9. Vorrichtung gemäß Anspruch 8, worin der Zündvorrichtungskreis mit zumindest einer externen Funkenstrecke (9) oder einem Schalter versehen ist.

Revendications

1. Procédé pour le revêtement d'un substrat, comprenant les étapes consistant à :

   - générer un faisceau pulsé d'un plasma d'ions et de particules non chargées d'un matériau de revêtement;
   - accélérer et guider les ions du faisceau de plasma suivant un champ magnétique incurvé jusqu'au substrat;
   - la courbure du champ magnétique étant choisie de façon que les particules non chargées du plasma n'atteignent pas le substrat.

2. Procédé selon la revendication 1, dans lequel le faisceau de plasma est engendré par la décharge d'un arc produit entre une cathode (1) constituée du matériau de revêtement et une anode (3).

3. Procédé selon la revendication 2, dans lequel la décharge de l'arc est pulsée.

4. Procédé selon l'une quelconque des revendications 1 à 3, dans lequel le champ magnétique incurvé est engendré par une bobine (4) ayant une forme incurvée.

5. Dispositif pour le revêtement d'un substrat comprenant :

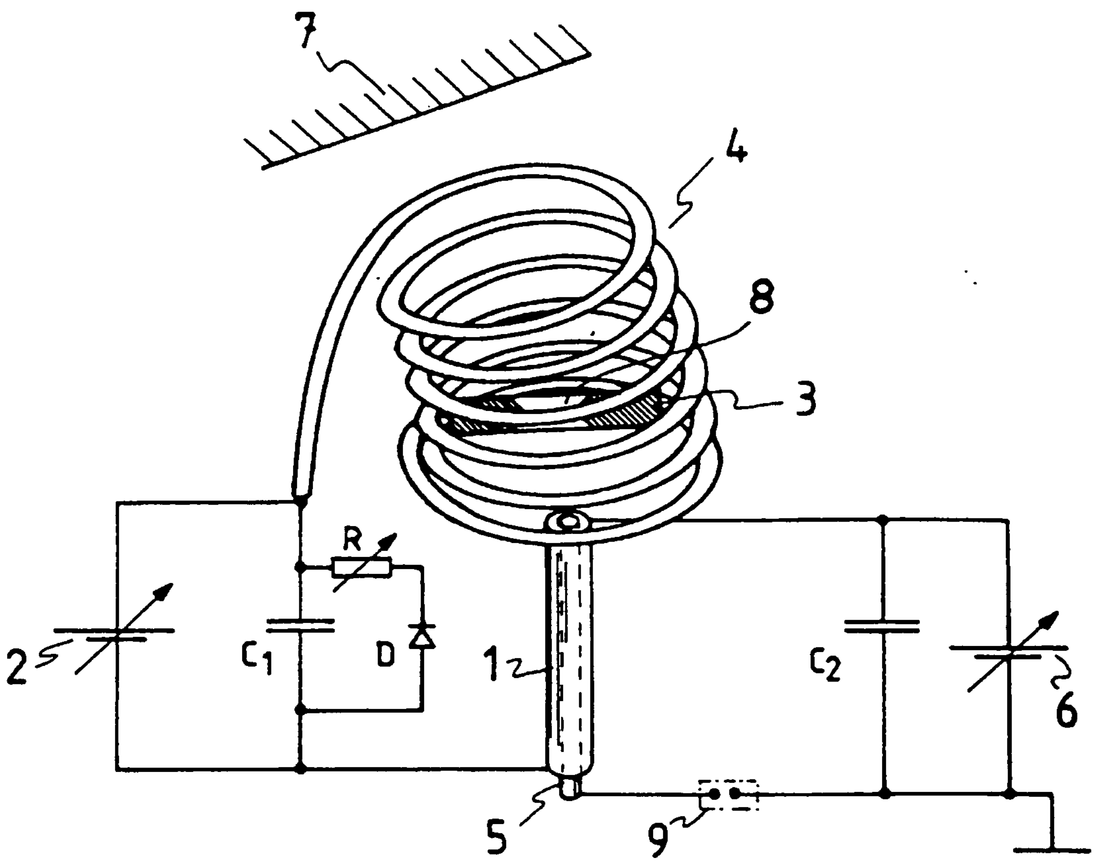
- une électrode de matériau de revêtement (1) et une autre électrode (3);
- au moins une source de tension (2) et au moins un condensateur (C1) pour produire un faisceau de plasma pulsé constitué du matériau de revêtement; et
- au moins une bobine de déflexion (4) pour produire un champ magnétique incurvé;
- le champ magnétique incurvé accélérant les ions du faisceau de plasma et guidant les ions vers le substrat (7) de sorte que les particules non chargées du faisceau de plasma iront directement au niveau du substrat (7).

6. Dispositif selon la revendication 5, dans lequel au moins l'une des électrodes (1, 3) est de forme cylindrique.

7. Dispositif selon l'une quelconque des revendications 5 et 6, dans lequel au moins l'une des électrodes est placée entièrement ou partiellement à l'intérieur de la bobine (4).

8. Dispositif selon l'une quelconque des revendications 5 à 7, comprenant en outre un circuit d'allumage pour produire un arc d'allumage entre l'électrode (1) en matériau de revêtement et l'autre électrode (3), le circuit d'allumage comportant une tige conductrice (5) à l'intérieur de l'électrode (1) en matériau de revêtement qui est de forme cylindrique, et comprenant un autre condensateur (C2) et une source de tension (6).

9. Dispositif selon la revendication 8, dans lequel le circuit de l'allumeur comporte au moins un éclateur externe (9) ou un commutateur.


7
4
8
3
R
2
C1
D
1
C2
6
5
9